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GRAIN REFINEMENT THROUGH DESIGN MODIFICATION OF ECAP DIES

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ABSTRACT

The need for super-plasticity and high strength leads to the development of Severe Plastic Deformation (SPD) techniques. The strength of the material is directly dependent upon the grain size of the material. During the simulation of ECAP process, the initial die designed with sharp corner angle reveals metal flash. Metal flash may fail the tip of the billet. To avoid and control the metal flash, the intersecting channels are redesigned with radius of 3mm and reveals smooth flow. ECAP die 90^0 and 120^0 for square billets are made in H11 Steel channels, that are cut into 58×9.2×8.2mm for 90^0 machined in EDM process, similarly 120^0 die with 52×9.2×8.2mm are made, including the Punch are made in same material of 155×9.2×8.2mm, respectively. Aluminum Automobile scrap were selected and melted in the open hearth furnace, made round rods and square billets as per the die dimensions. Molybdenum di- sulphate, is used as a lubricant. Tensile Test was carried out for the Annelid specimen. Brinell hardness was checked and SEM test was carried out, for finding out the reason for the failure.

KEYWORDS: Severe Plastic Deformation (SPD) , ECAP, Ultrafine refinement(UFG), Microstructure & Strain rate

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Original Article

INTRODUCTION

Equal channel Angular (ECAP) is a process of producing ultra-fine grain (UFG) structure in bulk material. It was developed by Segal and it is the most severe plastic deformation (SPD). The principal of material grain size is used to make effects on material properties. More research is going on in ECAP, based on pure metals and metallic alloys. The Severe Plastic Deformation (SPD) is a process for deformation method, to produce more amount of ultra-fine grain or sub-micron grain, with mechanical and physical properties. The technique is used in this shape of the work piece, which will not be modified and the microstructure of the deformed metal result in improvement in the form of both physical and mechanical properties, like Tensile/Compression Strength, Yield Stress, elongation and fatigue life.

EXPERIMENTAL MATERIALS AND PROCEDURES

Material Selection and Characterization

H11 is a special alloy steel, categorized as chromium tool steel, because of its high toughness and hardness; it is well suited for hot work applications, involving very high loads. Typical applications are hot-work forging and extrusion dies, helicopter rotor blades, etc.

Image Analysis of H11 Die Steel

Metallographic Test is used, to analyses the microstructure of the specimen. A part of the specimen was cut from the sample. The face of the material is polished using four grade of the emery sheet, to obtain fine

polished outlook without scratch. The specimen is allowed to further polishing in grinding machine, with the addition of alumina. Then, Nital a mixture of 4% nitrogen and 96% of ethanol is applied partially, to the face of the specimen and dried for 5 minutes. Then, the specimen is placed under electron microscope, to obtain clear microstructure.

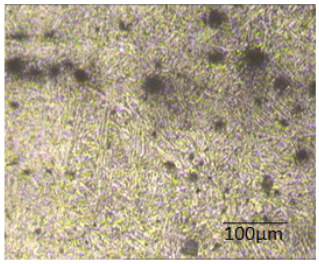

Figure 1: Micro Structure of H11 Die Steel

Image Analysis of Scrap Melted Al Alloy

Metallographic Test is used to analyze the microstructure of the specimen. A part of the specimen was cut from the sample. The specimen is of the aluminum alloy, made from automobile AL scrap. The face of the material is polished using four grade of the emery sheet, to obtain fine polished outlook without scratch. Then, Nital a mixture of 4% nitrogen and 96% of ethanol is applied partially to face of specimen and dried for 5 minutes. Then, the specimen is placed under electron microscope to obtain clear microstructure.

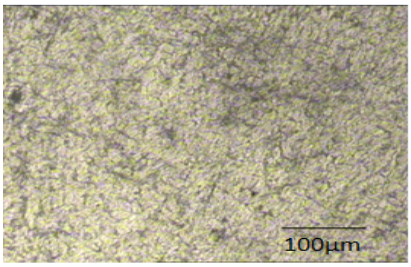

Figure 2: Micro Structure of Scrap Melted Aluminum Alloy

Chemical Composition

To analyze the composition of the material, chemical composition test was carried out using PAA (Portable Alloy Analyzers in SPF).

Figure 3: Square Plate

Figure 4: Scrap melted of Al Alloy Circular Rod

The result of the sample was tested as per the specification, for the Aluminum composite. Table one, shows the composition of the Automobile Aluminum Scrap.

Table 1

Si	9.77
Al	81.18
Mg	5.34
Pb	0.09
Zn	1.30
Cu	0.91
Ni	0.09
Fe	0.99
Mn	0.18
Cr	0.16

Figure 5: ECAP Die with Punch

Hardness Test

Brinell hardness testing machine is used to measure the hardness of the specimen.

For consideration of Automobile AL Scrap Diamond intender is chosen, as per standards and Hardness of the specimen is measured. The results obtained using Brinell hardness testing is shown in Table 1.

Table 2

No of Pieces	Temperature	Time	BHN
1st	350c	1hr	48.3HB
2nd	350c	2hr	49.2HB
3rd	350c	3hr	49.3HB

Table 3

Si	22.48
Al	73.12
Sn	0.05
Pb	0.27
Zn	1.38
Cu	1.28
Ni	0.21
Fe	0.97
Mn	0.14
Cr	0.11

- UTM machine is used for pressing Force applied 70KN
- At 70KN Round Rod broken inside the ECAP Die
- Fracture Reveals like Brittle
- It was found that the circular rods and square plate to be heat treated for further fabrication

Fractured Round Rod Specimen

Figuer 6

Image shows fractured components of round rod, during ECAP process in 110^0 die, under the load of 70KN

- Tensile test was conducted on heat treated specimens, as per ASTM E8 standard
- Equipment used UTM machine model UTN 40

Figure 7

- Image shows tensile specimen of heat treated samples machined as per ASTM E8 standard
- From Tensile Test report heat treated sample of 350^0C at 3hr shows increased tensile strength 147.77Mpa.
- Heat treated square plate samples are machined and prepared as per the Die requirements.
- In both die 90^0 and 120^0 channel surface, punch bottom surface, samples are well lubricated by Molybdenum Di sulphate.
- Samples are fabricated at room temperature in UTM machine with load applied constantly is 50KN.
- Samples are fractured in both the dies and punch is found slight bend at the top neck in 120^0 die fabrication.

FABRICATION OF ECAP DIES WITH PUNCH

Equal Channel Angular Pressing (ECAP) means that its channel having the same crosses section throughout the channel. It is used for structural and landing gear application. Here ECAP of 90^0 & 120^0 Die have been manufactured in SPF.

- H11 tool steel was selected
- For the specified Dimension H11 steel was machined
- First surfaces are grounded and made a holes and pins
- Flow channel prepared EDM machine with special copper electrode

Fabrication of ECAP Die of 90^0

Figure 8: Ecap Die of 90^0

Fabrication of ECAP Die of 120^0

Figure 9: Ecap Die of 120^0

Fabrication of Punch

Fabrication of Punch was done with the H11 Die Tool Steel. It is used for pressing the material inside the ECAP Die with uniform load.

Figure.10: Punch of Ecap Dies

Specification of Punch

Total length: 155mm

Thickness: 8.2mm

Width: 9.2mm

RESULT & DISCUSSIONS

Figure.11: Image Shows Fractured Sample in 90^0 Die

Figure 12: Image Shows Fractured Sample in 120^0 die

SEM Image (Failure Analysis Report)

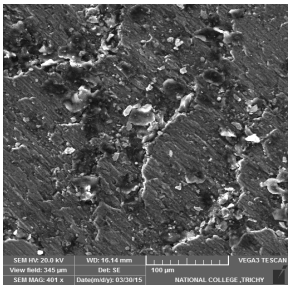

Figure 13: SEM Image of Fractured Specimen

From the Tensile test, it is observed that round samples are failed like brittle fracture in 110^0 die. Sample composition shows enrichment of silicon during the melting of Al – Si alloy to add Si stabilizer like sodium in melting. From phase 1 review simulation, the simulation results found in both die with curvature radius in corner maintained 3mm results metal flow smoothly without any metal flash. Also, melting of aluminum in exposed atmosphere results formation of porosity and embrittlement. Heat treated square billets are fractured in both the dies and it shows ductile form of fracture due to the Si present in the sample and porosity in it. From SEM image Dimple region reveals ductile form of fracture.

CONCLUSIONS

- Design and simulation of ECAP Die result show metal can be fabricated without any metal flash.
- During the melting of Al-Si alloy should be performed in Vacuum furnace or inert gas equipped furnace**.**
- During charging of scrap, Si stabilizers like sodium should be added.
- Heating coil should be introduced in the die to fabricate the metals at high temperature or maintain annealed temperatures
- Also start practice fabricating with low melting and low dense materials like pure Al, Cu, and Mg alloys.

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